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09/681,857	06/19/2001	Subhasish Roychoudhury	RD-27738	7086

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EXAMINER

STEVENS, THOMAS H

ART UNIT	PAPER NUMBER
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2123

DATE MAILED: 03/25/2005

Please find below and/or attached an Office communication concerning this application or proceeding.

**Office Action Summary**

Application No.

09/681,857

Applicant(s)

ROYCHOUDHURY, SUBHASISH

Examiner

Thomas H. Stevens

Art Unit

2123

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

- 1) ☒ Responsive to communication(s) filed on 03 January 2005.
- 2a) ☒ This action is **FINAL**. 2b) ☐ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

- 4) ☒ Claim(s) 1,3-6 and 8-14 is/are pending in the application.
- 4a) Of the above claim(s) 2 and 7 is/are withdrawn from consideration.
- 5) ☐ Claim(s) \_\_\_\_\_ is/are allowed.
- 6) ☒ Claim(s) 1,3-6 and 8-14 is/are rejected.
- 7) ☐ Claim(s) \_\_\_\_\_ is/are objected to.
- 8) ☐ Claim(s) \_\_\_\_\_ are subject to restriction and/or election requirement.

**Application Papers**

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☐ The drawing(s) filed on \_\_\_\_\_ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.  
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).  
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All b) ☐ Some \* c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.
3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

\* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

- 1) ☒ Notice of References Cited (PTO-892)
- 2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
- 3) ☐ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08)  
Paper No(s)/Mail Date \_\_\_\_\_
- 4) ☐ Interview Summary (PTO-413)  
Paper No(s)/Mail Date. \_\_\_\_\_
- 5) ☐ Notice of Informal Patent Application (PTO-152)
- 6) ☐ Other: \_\_\_\_\_

**DETAILED ACTION**

1. Claims 2, 7 were cancelled.
2. Claims 12-14 were added.
3. Claims 1,3-6, 8-14 were examined.

***Response to Applicant's Argument***

**35 USC § 112**

4. Applicants are thanked for addressing this issue. The word "systems" has not been amended, thus rejections to claims 6-10 stand; however rejection to claim 7 is withdrawn.

**35 USC § 101**

5. Applicants are thanked for addressing this issue. The rejection stands since claims 1-5, 11-14 are precarious as to whether the computer or an outside agency is executing these events.

**35 USC § 102**

6. Applicants are thanked for addressing this issue. Based on amended claims, rejection is withdrawn.

***Final Rejection (2<sup>nd</sup> Office Action)***

***Claim Rejections - 35 USC § 101***

7. 35 U.S.C. 101 reads as follows:

Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title.

8. Claims 1-5, 11-14 are rejected under 35 U.S.C. 101 because the claims are precarious as to whether the computer or an outside agency is executing these events.

***Claim Rejections - 35 USC § 112***

9. The following is a quotation of the second paragraph of 35 U.S.C. 112:

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter, which the applicant regards as his invention.

10. Claims 6-10 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. Regarding claims 6-10, the phrase "system" renders the claim indefinite because it is unclear whether the limitations following the phrase are part of the claimed invention nor properly distinguishing which statutory type is being claimed. See MPEP § 2173.05(d).
11. Regarding claim 12, the phrase "adapted" renders the claim indefinite because the claim includes elements not actually disclosed, thereby rendering the scope of the claim unascertainable. See MPEP § 2173.05(d).

***Claim Rejections - 35 USC § 103***

12. The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.

4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

13. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

14. Claims 1-15 are rejected under 35 U.S.C. 103 (a) as unpatentable by Doughty et al. (U.S. Patent 6,222,147 (2001)) in view of Schlitz ("Simulation of Gas Dynamics and Electromagnetic Process in High-Current Arc Plasmas" (1998)). Doughty et al., teaches an improved baffle for a circuit protective devices thereby effectively controlling arc pressure and arc effluent during short circuit interruption but doesn't teach how to simulate it. Schlitz teaches a strategy to numerically study thermal plasma arc columns under high-current conditions (pg. iv).

At the time of invention, it would have been obvious to one of ordinary skill in the art to modify Schlitz by way of Doughty et al. since it would have been beneficial to simulate electrical circuit protective devices (Doughty: column 2, lines 53-56).

Claim 1. A method for modeling electric arc behavior (Schlitz: pg. 122, title and paragraphs 1-3), said method comprising the steps of: determining electrical conductivity distribution in an arc (Schlitz: pg. 126, 3<sup>rd</sup> paragraph) based upon a temperature distribution and pressure distribution within an arc chamber (Doughty:

columns 5 and 6, lines 63-67, lines 19) in which are disposed a stationary contact, a movable contact and a plurality of adjacent arc chute plates (Doughty: column 3, lines 10-15); and determining a current density distribution of the arc based on the determined electrical conductivity (Schlitz: pg. 136, lines 1-3, Biot-Savart Law).

Claim 3. A method according to Claim 1 (Schlitz: pg. 122, title and paragraphs 1-3; pg. 126, 3<sup>rd</sup> paragraph; Doughty: columns 5 and 6, lines 63-67, lines 19; Doughty: column 3, lines 10-15) wherein determining current density distribution comprises the step of determining electrical potential of the arc (Schlitz: pg. 137, lines 3-6).

Claim 4. A method according to claim 1 (Schlitz: pg. 122, title and paragraphs 1-3; pg. 126, 3<sup>rd</sup> paragraph; Doughty: columns 5 and 6, lines 63-67, lines 19; Doughty: column 3, lines 10-15) further comprising the steps of: determining magnetic fields (Schlitz: pg. 138, lines 13-17) and Joule heating (Schlitz: pg. 132, lines 1-18 and pg. 136, lines 14-15) using the determined current density distribution (Schlitz: pg. 136, lines 1-3, Biot-Savart Law); and determining magnetic forces from the determined magnetic fields (Schlitz: pg. 123, 2<sup>nd</sup> paragraph).

Claim 5. A method according to claim 4 (Schlitz: pg. 122, title and paragraphs 1-3; pg. 126, 3<sup>rd</sup> paragraph; Doughty: columns 5 and 6, lines 63-67, lines 19; Doughty: column 3, lines 10-15) further comprising the step of determining gas dynamics field using the

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determined Joule heating (Schlitz: pg. 132, lines 1-18) and magnetic forces (Schlitz: pg. 145, lines 1-3).

Claim 6. A system for modeling electric arc behavior (Schlitz: pg. 122, title and paragraphs 1-3), said system comprising: at least one computer configured to determine at least an electrical conductivity distribution in an arc within an arc chamber (Doughty: columns 5 and 6, lines 63-67, lines 19) based upon a temperature distribution and a pressure distribution within the arc chamber in which are disposed a stationary contact, a movable contact and a plurality of adjacent arc chute plates (Doughty: column 3, lines 10-15), or a current density distribution of the arc based on the electrical conductivity distribution in the arc.

Claim 8. A system according to Claim 6, (Schlitz: pg. 122, title and paragraphs 1-3; Doughty: columns 5 and 6, lines 63-67, lines 19; Doughty: column 3, lines 10-15) wherein the at least one computer is configurable to determine an electrical potential of the arc (Schlitz: pg. 137, lines 3-6).

Claim 9. The system according to claim 6, (Schlitz: pg. 122, title and paragraphs 1-3; Doughty: columns 5 and 6, lines 63-67, lines 19; Doughty: column 3, lines 10-15) wherein the at least one computer is configurable to determine joule heating and/or magnetic fields base on the current density distribution (Schlitz: pg. 137, lines 3-60 and magnetic forces from the determined magnetic fields (pg. 123, 2<sup>nd</sup> paragraph)).

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Claim 10. The system according to claim 6, (Schlitz: pg. 122, title and paragraphs 1-3; Doughty: columns 5 and 6, lines 63-67, lines 19; Doughty: column 3, lines 10-15) wherein the at least one computer is configurable to determine a gas dynamics field based on at least the joule heating or the magnetic fields (Schlitz: g. 145, lines 1-3).

Claim 11. A computer readable media, comprising: code adapted (Schlitz: Appendix: V) to determine at least an electrical conductivity distribution in an arc within an arc chambers (Doughty: columns 5 and 6, lines 63-67, lines 19) based upon a temperature distribution (Schlitz: pg.231-232) and a pressure distribution within an arc chamber in which are disposed a stationary contact, a movable contact and a plurality of adjacent arc chute plates (Doughty: column 3, lines 10-15).

Claim 12. The computer readable media of claim 11, (Schlitz: Appendix: V; Doughty: columns 5 and 6, lines 63-67, lines 19; Doughty: column 3, lines 10-15) further comprising code determine a current density distribution of the arc based on the electrical adapted to conductivity.

Claim 13. The computer readable media of claim 12, (Schlitz: Appendix: V; Doughty: columns 5 and 6, lines 63-67, lines 19; Doughty: column 3, lines 10-15) further comprising code adapted to determine magnetic fields and Joule heating using the current density distribution (Schlitz: pg. 137, lines 3-60 and magnetic forces from the determined magnetic fields (pg. 123, 2<sup>nd</sup> paragraph)).



Claim 14. The computer readable media of claim 13, (Schlitz: Appendix: V; Doughty: columns 5 and 6, lines 63-67, lines 19; Doughty: column 3, lines 10-15; Schlitz: pg. 137, lines 3-60 and magnetic forces from the determined magnetic fields (pg. 123, 2<sup>nd</sup> paragraph)) further comprising code adapted to determine magnetic forces from the magnetic fields (Schlitz: pg. 123, 2<sup>nd</sup> paragraph).

### ***Conclusion***

15. **THIS ACTION IS MADE FINAL.** Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

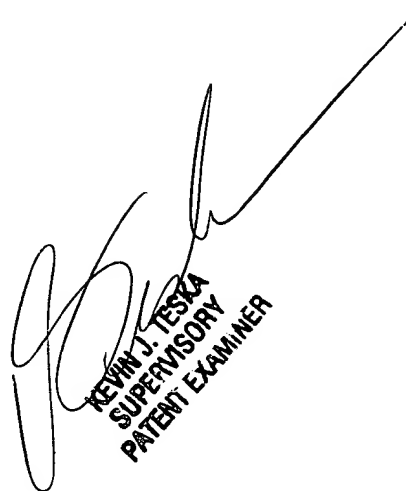
### ***Correspondence Information***

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Mr. Tom Stevens whose telephone number is 571-272-3715, Monday-Friday (8:00 am- 4:30 pm) or contact Supervisor Mr. Kevin Teska at (571) 272-3716. Fax number is 571-273-3715

Any inquires of general nature or relating to the status of this application should be directed to the Group receptionist whose phone number is (571)272-1400

March 17, 2005

THS



KEVIN J. TESKA  
SUPERVISORY  
PATENT EXAMINER

# SPECIFICATION

Electronic Version 1.2.8

Stylesheet Version 1.0

## METHODS AND SYSTEMS FOR ARC INTERRUPTION MODELING

### Background of Invention

- [0001] This invention relates generally to circuit breakers, and more particularly, to modeling arc interruption.
- [0002] A circuit breaker typically includes a stationary contact and a movable contact located in an arc chamber. During normal operation, i.e., when no fault occurs, the movable contact is in electrical contact with the stationary contact, and current at a rated level flows through the breaker.
- [0003] Once a fault occurs, the movable contact moves away from the stationary contact to interrupt current flow. When such interruption occurs, an arc is generated between the movable and stationary contacts and the electricity at the electrodes, i.e., the contacts, causes the medium (e.g., air, SF6) between the electrodes to ionize, commonly referred to as a plasma stage. The temperature of the medium in the plasma stage ranges between, for example, 10,000 – 20,000 K. At such temperatures, ionized iron, silver and other kinds of vapors from the electrodes, or other materials in the vicinity of the arc, contribute to the plasma.
- [0004] Various techniques can be used to extinguish an arc. Such techniques include, for example, cooling the arc via an ablative medium, stretching the arc by taking advantage of its self-induced and external magnetic field, and pushing the arc (via the influence of flow expansion and magnetic fields) inside arc chutes or splitter plates. If the arc voltage drop along with the voltage drop across a system impedance are higher than the system voltage, the arc extinguishes and stays extinguished.

[0005] The physics governing the ionized plasma stage can be described as a coupling between gas dynamics, electrostatics and electromagnetism. Specifically, the electric field affects the energy equations via Joule heating, and the electromagnetic field along with the current flowing through the plasma affects the flow field via Lorentz forces. Gas dynamic equations, which are inherently non-linear in nature become more complex and non-linear because of the additional interactions with other types of physics.

[0006] At least some known arc behavioral models are generated based on empirical studies, and depend on experimental data. The variables in other types of circuit breakers, as well as under different operating conditions, alter arc behavior. Therefore, such models are not extendible to other types of breakers nor are such models for same type of breakers under different operating conditions. As a result, and in creating and attempting to optimize breaker design, numerous breakers typically are tested under various short circuit conditions, and different design types are evaluated using a build-and-bust mode. Such design techniques may not result in an optimized design. In addition, such techniques require time and resources, which increase the cost of circuit breaker design and development.

## Summary of Invention

[0007] In one aspect, a method for modeling electric arc behavior is described. The method includes the steps of determining electrical conductivity distribution in an arc, and determining a current density distribution of the arc based on the determined electrical conductivity. In an exemplary embodiment, the electrical conductivity distribution in the arc is determined using temperature and pressure distribution with an arc chamber. The current density distribution is determined using the electrical potential of the arc. Further, the magnetic fields and Joule heating are determined using the determined current density distribution, and magnetic forces are determined using the determined magnetic fields.

[0008] In another aspect, a system for modeling electric arc behavior is described. The system includes, in an exemplary embodiment, a server computer, a first client computer coupled to the server computer, and a second client computer coupled

to the server computer. The first client computer is programmed to determine electrical conductivity distribution in an arc, and the second client computer is programmed to determine a current density distribution of the arc based on the determined electrical conductivity.

## Brief Description of Drawings

- [0009] Figure 1 is a schematic diagram of an arc chamber.
- [0010] Figure 2 is a schematic diagram of a system architecture.
- [0011] Figure 3 is a data flow diagram for performing computational fluid dynamics analysis.

## Detailed Description

- [0012] Figure 1 is a schematic diagram of a typical arc chamber 10 of a breaker. Chamber is defined by a breaker case 12, and conductors designated as stationary 18 and movable contacts 20 are located in arc chamber. Contacts are in a normally closed condition so that current at a rated level can flow through the breaker. An arc chute 22 also is located in arc chamber. Arc chute includes a plurality of spaced plates.
- [0013] In a first mode of operation, i.e., normal operation, movable contact 20 is in electrical contact with stationary contact 18, and current at a rated level flows through the breaker. In a second mode of operation, i.e., if a fault occurs, movable contact 20 moves away from stationary contact 18 to interrupt current flow, as illustrated in phantom in Figure 1. When movable contact 20 moves away from stationary contact 18, an electric arc is generated. Also, when in the second mode, the electricity at the electrodes, i.e., the contacts, causes the medium (e.g., air, SF<sub>6</sub>) between the electrodes to ionize, resulting in a plasma stage. The temperature of the medium in the plasma stage ranges between, for example, 10,000 – 20,000 K. At such temperatures, ionized iron, silver and other kinds of vapors from the electrodes, or other materials in the vicinity of the arc, contribute to the plasma and can change arc properties.

[0014] The generated arc moves outward from contacts and is directed into arc chute 22. Specifically, the arc is split by the plates and the split portions of the arc are directed into spaces between adjacent plates 24. As a result of such splitting of the arc, the arc voltage increases and the arc is extinguished.

[0015] A model for determining arc behavior is described below. Such arc behavior model can be used, for example, in developing arc chute configurations for extinguishing arcs, as well as developing other mechanisms for extinguishing arcs.

[0016] More specifically, and referring to Figure 2, a system 30 for modeling arc behavior includes a server 32 that communicates with client computers. Server and client computers are, in one embodiment, personal computers. One client computer is programmed to perform computational fluid dynamics (CFD) analysis 34 and other client computer is programmed to perform magnetostatics analysis 36. Of course, the specific architecture illustrated in Figure 2 is exemplary only, and rather than having a client-server architecture, both the CFD analysis and the magnetostatics analysis could be performed on one computer, or on separate computers coupled via a network, such as a local area network or a wide area network (not shown).

[0017] Regarding client computer programmed to perform CFD analysis, a commercially available CFD software program, such as the Fluent program commercially available from Fluent Inc., is stored in computer memory. Of course, other commercially available CFD programs can be utilized. The Fluent program uses a set of partial differential equations commonly referred to as Navier Stokes equations and enthalpy or energy equations, along with an equation of state. The Fluent program generates values for flow velocity, pressure and temperature distributions in the plasma domain.

[0018] Further, using the user defined programming feature in the Fluent program, equations are incorporated into the Fluent program to extend the program capabilities. The equations incorporated into the Fluent program are set forth below. The terms that are underlined are not in the commercially available Fluent program and therefore, such terms are added to the program via the user defined

programming feature.

[0019] Generally, the equations set forth below extend the commercially available Fluent program to capture the physics typical for an electric arc and the plasma stage. Radiation is defined using an optically thin medium approximation, while the plasma properties are defined as a function of temperature and pressure. An additional set of partial differential equation is provided to solve for electric potential, and the current densities are derived based on their relation to electric potential. The magnetic flux is evaluated using Biot-Savart law, which is an integral equation, relating the electric field and the position vectors.

- Continuity Equation

$$\frac{\partial \rho(T, p)}{\partial t} + \nabla \cdot (\rho(T, p) \vec{V}) = 0$$

- Momentum Equation:

$$\frac{\partial \rho(T, p) \vec{V}}{\partial t} + \nabla \cdot (\rho(T, p) \vec{V} \vec{V}) = \vec{J} \times \vec{B} + \rho(T, p) \times \vec{g} - \nabla p + \nabla \cdot \vec{\tau}$$

- Enthalpy Equation

T, p

$$\frac{\partial \rho(T, p) h(T, p)}{\partial t} + \nabla \cdot (\rho(T, p) \vec{V} h(T, p)) = \nabla \cdot (k(T, p) \nabla T) + \frac{\partial \rho}{\partial t} + \nabla \cdot (p \vec{V}) - \vec{S}_h(T, p) + \vec{J} \cdot \vec{E} + \phi$$

- Equation of state:

$$p = \rho RT$$

- Species Transport Equation

$$\frac{\partial \rho(T, p)}{\partial t} + \nabla \cdot (\rho(T, p) \vec{V}) = 0$$

- Current Continuity Equation:

$$\nabla \cdot (\sigma(T, p) \nabla \Phi) = 0$$

- where, Current density:

$$\vec{J} = \sigma(T, p) \cdot \vec{E} = -\sigma(T, p) \cdot \nabla \Phi$$

- Magnetic Flux Density:

$$\vec{B}(\vec{r}) = \vec{B}(\vec{r})_{\text{ext}} + \frac{\mu_0}{4\pi} \iiint \vec{J}(\vec{r}') \times \frac{\vec{r} - \vec{r}'}{|\vec{r} - \vec{r}'|^3} dV'$$

[0020] In order to define additional quantities to be solved for, or any other physical quantities for post-processing, the Fluent program requires users to define user defined scalars (UDS). For a two-dimensional and axi-symmetric implementation of the plasma modeling, up to 8 UDSs are used, while for a three-dimensional implementation, 15 UDSs are used.

[0021] Client computer is programmed using a commercially available electromagnetic software program such as the MagNet program commercially available from Infolytica Corporation. Of course, other electromagnetic software can be utilized. The MagNet program solves a set of partial differential equations commonly referred to as Maxwell's equations.

[0022] In operation, and as explained above, client computer in which the Fluent program resides solves the electro-statics equation. The electrical conductivity, which is a function of temperature distribution, is evaluated throughout the plasma region and stored in a defined file format by the Fluent program. The file, generated by the Fluent program, is communicated via server 32 to client computer in which the MagNet program resides. Once the file is transferred to client computer, the MagNet program uses the electrical conductivity distribution in the plasma region from the file and solves the magneto-static equations to generate a magnetic flux and electric flux density distribution. The magnetic flux and electric flux density distribution are stored in a defined file format by the MagNet program.

[0023] The file generated by the MagNet program is then transferred, via server 32, to client computer in which the Fluent program resides. The file from the MagNet program is then used by the Fluent program for the next iteration of calculations. Specifically, once the magnetic flux and electric flux density is determined by the MagNet program, these terms are used to determine the source term in the momentum and energy equation in the Fluent program.

[0024] The Fluent program in client computer remains active throughout the entire process. If the Fluent program is terminated while transferring the file and running the MagNet program, the transient analysis would lose information about previous



time step or iteration, which would hinder proper transient simulation.

[0025] In addition, the circuit equations are coupled with field equations, i.e. the gas dynamics, electrostatics and magnetostatics equations. Depending on the arc resistance, which is a function of temperature, the overall impedance of the system under arcing conditions dynamically changes as the flow and temperature field changes. As a result, overall current at the electrode also changes. This dynamic behavior can be solved by coupling the circuit equations with the field equations. Therefore, the circuit equations are solved to provide the appropriate boundary conditions for the electrostatic equations.

[0026] Figure 3 is a data flow diagram 50 illustrating a sequence for modeling arc behavior. Specifically, electrical conductivity distribution in an arc is determined using the Fluent program in client computer. On the first iteration, electrical conductivity distribution is based on temperature and pressure distribution 52 as well as plasma parameters 54. The electrical conductivity values are stored in the defined file format by the Fluent program, and then communicated to client computer in which the MagNet program resides. The MagNet program then determines current density distribution 56 based on the electrical potential 58 determined from the electrical conductivity 60. The MagNet program also determines magnetic fields 62, magnetic forces 64, and Joule heating 66 from the current density distribution. The determined Joule heating and magnetic forces, along with the previously determined plasma parameters, are then used for determining gas dynamics field 68. For a next iteration, the gas dynamics field are then used to determine temperature and pressure distribution 70.

[0027] While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.